BULLETIN

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OHIO AGRICULTURAL EXPERIMENT STATION.

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ARTICLE XII.—FORTY YEARS OF WHEAT CULTURE IN OHIO.

Ohio lies within the borders of what is known as the winter wheat belt of the United States—a region, the soil and climate of which are especially adapted to the culture of this cereal. The State possesses two great natural arteries of traffic, one on its northern and one on its southern boundary, and before the advent of the railway it was crossed by two lines of canals, each extending from the lake on the north to the river on the south, and affording outlets for its productions that served a very important function in its early history. Lying as it does, right in the gateway between the East and the West, it has been crossed by line after line of the great transcontinental railways, while its rich mineral resources have caused the building of multitudes of other lines, running in all directions, until its territory is now traversed by a network of railways, aggregating within the State nearly 8,000 miles of main track, besides more than 2,000 miles of sidings.

Under such circumstances it is not surprising that the culture of wheat became at an early date and has ever continued to be a leading branch of Ohio's agriculture, and that the State should not only have liberally supplied itself with bread, but have had much to spare.

Because of this relative prominence of wheat culture in the agriculture of the State, the Experiment Station has made the study of wheat a leading feature of its work, and the statistical study which follows has been undertaken primarily for the purpose of obtaining such assistance as it might give in the conduct of the Station's experimental research. It was hoped that this study might throw some light upon such problems as the relative adaptability to wheat culture of soils of different geologic

origin and history, and the effect of differences of latitude, of drainage and the use of commercial fertilizers, and it is believed that some of the conclusions which it seems to warrant should be carefully considered by the farmers of large areas of the State.

TOTAL YIELD OF WHEAT.

Since 1850 the township assessors of Ohio have been required to collect statistics showing the acreage and yield of wheat in their townships for each year. The following table gives the total yield and average yield per acre for the State for each year during the forty years ending with 1889; the total yields by periods of ten years and twenty years, and the means of the average yields for the ten and twenty-year periods:

TABLE I.—TOTAL AND AVERAGE YIELD OF WHEAT IN OHIO FOR FORTY YEARS.

Year.	Yield.		Year.	Yield.	
	Total.	Average per acre.		Total.	Average per acre.
	Bushels.	*Bushels.*		*Bushels.*	*Bushels.*
1850	31,500,000	18.0	1870	18,726 341	11.3
1851	25,309,225	15.2	1871	22,274,328	13 3
1852	23,043,737	14.1	1872	18,987,664	11.2
1853	17,118,311	12 0	1873	21,974 385	12 6
1854	11,980,110	8 0	1874	26 896,818	14.5
1855	19,569,320	13 8	1875	17,867,967	9.2
1856	15,333,837	10 2	1876	15,354,569	10.2
1857	25,397,614	14 0	1877	27 306 566	15.6
1858	17,655,483	10.4	1878	35,218,783	16.6
1859	13,317,967	7.2	1879	41,052,120	17.8
10 years	200,225,604	12.3	10 years	245 659,541	13.4
1860	23,640,356	12.7	1880	48,540,307	17.2
1861	20,055,424	10.4	1881	38,102,633	13 8
1862	29,783,651	14 2	1882	42,112,403	15.6
1863	20,452,410	11.5	1883	27,169,738	10.7
1864	15,541,385	9.3	1884	36,396,119	14.4
1865	13,234,139	8.5	1885	24,183,430	9.8
1866	6,150,798	4.8	1886	37,661,681	14.0
1867	13,851,266	11.9	1887	34,364,174	13.4
1868	16,480,059	11.3	1888	26,160,994	11.8
1869	26,499,729	15.4	1889	31,663,448	14.6
10 years	175,843,862	11.0	10 years	346,354,927	13.7
20 years	376,059,466	11.6	20 years	592,014,468	13.6

This table shows that the total yield and average rate of production diminished during the second decade, as compared with the first; that there was a marked increase during the third decade, and that during the

fourth decade there was a small increase in rate of production but a very large increase in total yield, the result of a great increase in acreage.

How much of the falling off of production during the sixties was due to climatic causes and insect ravages; how much to the calling away of multitudes of farmers and farm laborers into the armies of the Union and the attempt of those left at home to cultivate a larger area than could be handled properly, and how much to superficial exhaustion of soil under a thoughtless system of husbandry, would be impossible to estimate. Doubtless each of these factors had a share in bringing down the rate of production.

During the first seven years of the third decade no progress was made, either in total production or in production per acre; but with the large yields and high prices of the last three years of this period the total production mounted rapidly upward, and notwithstanding the discouragingly low prices which have prevailed during the latter half of the last decade, the average total production has been nearly double what it was during the sixties, and forty per cent. greater than during the seventies

CROP FAILURES.

It will be noticed that during the forty-year period under consideration there have been seven seasons in which the average yield for the State fell below ten bushels per acre. In 1854 the crop was almost totally destroyed in the northern and northeastern counties and seriously injured through the central counties by the Wheat Midge (*Diplosis tritici*) commonly called "red weevil." In 1859 the wheat was injured by a severe frost on the night of the 5th of June, which found the wheat over a large portion of the State in bloom, and caused an immense injury to the crop, especially in the central and eastern portions of the State.

In 1864 the crop was injured by the great freeze of January 1st, which killed the plants in the ground. In 1865, freezing out in spring, a wet harvest with much rust, causing failure to fill out, the midge and "scab" all contributed to the reduction of the harvest; and in 1866 "winter killing," especially during the latter part of winter, so reduced the crop that many counties did not produce sufficient for seed.

This was the culmination of three years of disaster for the wheat grower, and many farmers were ready to believe that wheat culture could no longer be made profitable in Ohio. So great was the discouragement that the total area sown in the State, which had reached 2,090,000 acres in 1862, was reduced to 1,161,000 acres in 1867, notwithstanding the great stimulus to production afforded by the abnormally high prices of the later years of the war.

In 1875 there was some injury from winter killing, but the greatest source of loss was the wet harvest, rains beginning about the middle of June and continuing almost daily until August, causing the wheat to rust badly and also to sprout in the shock.

The injury of 1885 was chiefly caused by intense cold during the winter when the ground was nearly bare of snow, freezing the plants in the ground as in 1864. Many counties in the northern and northwestern part of the State had snow covering this winter, and these report an excellent yield.

From 1877 to 1882 were six years of exceptionally fine harvests. The two-million-acre mark was passed for the second time in the crop of 1878, and by 1881 nearly 3,000,000 acres were in wheat, or nearly an acre for each inhabitant of the State.

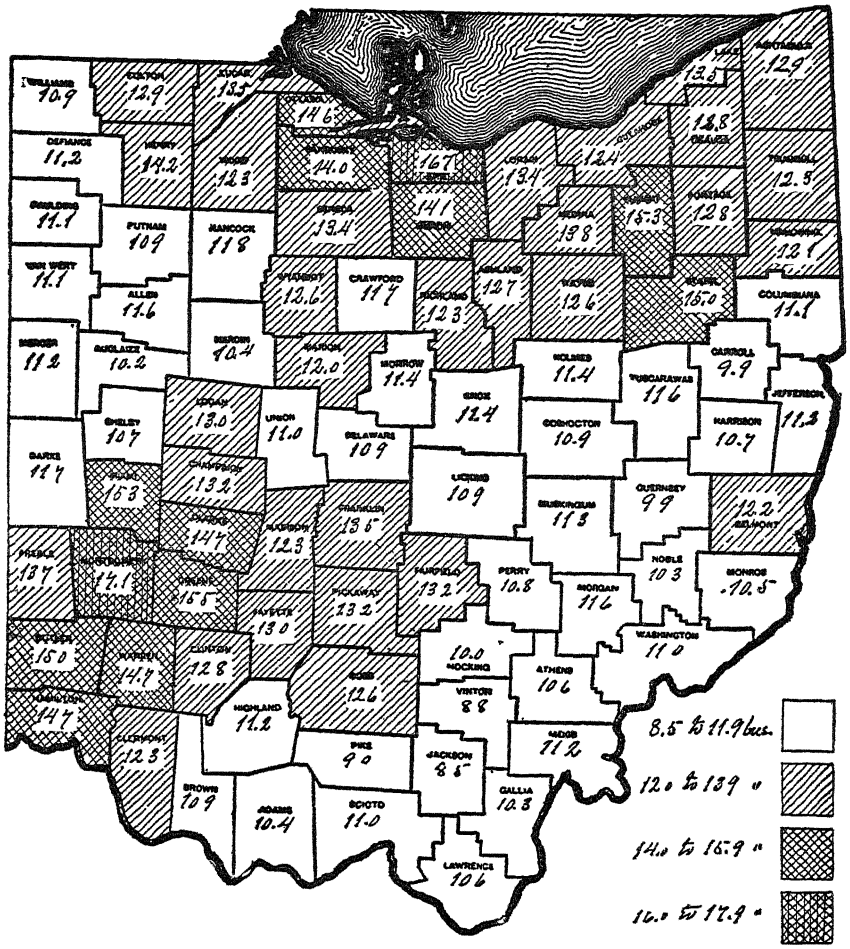
But with the failure of 1885 came another source of discouragement, in the shape of a falling market. Year after year the price of wheat fluctuated with monotonous regularity between seventy and ninety cents per bushel, while the average product per acre, though generally equal to or a little greater than the average for the thirty years ending with 1879, was still far below that of the six fat years noted, and there has probably been no time within the history of our State when its farmers were so generally and so deeply discouraged as they have been during the five years just past.

By the aid of the following maps and tables we may be able to trace the course of wheat production in each county in Ohio, through the forty years under consideration. These maps and tables have been compiled from the statistics collected by the township assessors of the State, and while it must be acknowledged that their statistics are ultimately based upon mere estimates and not upon accurate weights and measurements, and that many inaccuracies have crept in during the processes of compilation and printing, yet it can not but be admitted that, taken as a whole, they furnish a fair index to the general condition of this industry in the State.

AVERAGE YIELD PER ACRE.

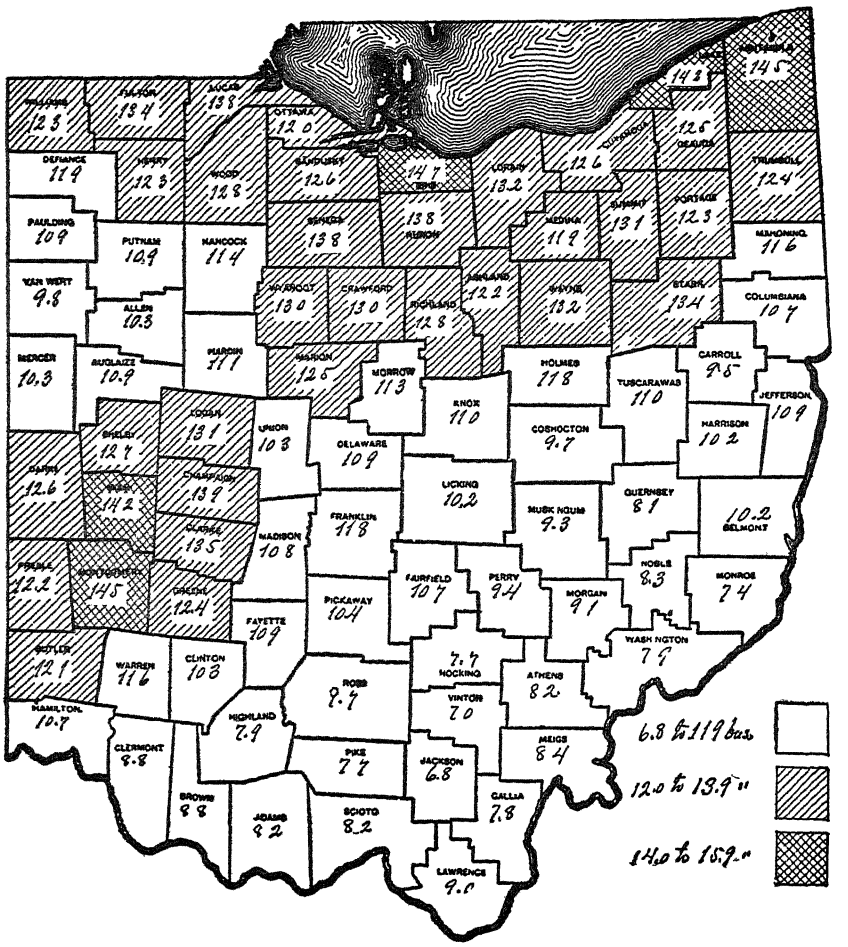
Maps I to IV, inclusive, show the average yield of wheat per acre for each county during each of the ten-year periods already named.

MAP I.—AVERAGE YIELD OF WHEAT IN OHIO FOR THE TEN YEARS, 1850–59.



Map I shows that during the fifties the Miami valleys produced the largest crops of wheat, Montgomery county leading with an average of 17.1 bushels per acre, while another area of large production was found in the northern counties, Erie leading with an average of 16.7 bushels. In the Miami region Greene, Miami and Butler, and in the northern region Summit and Stark reached 15 bushels or over during this period.

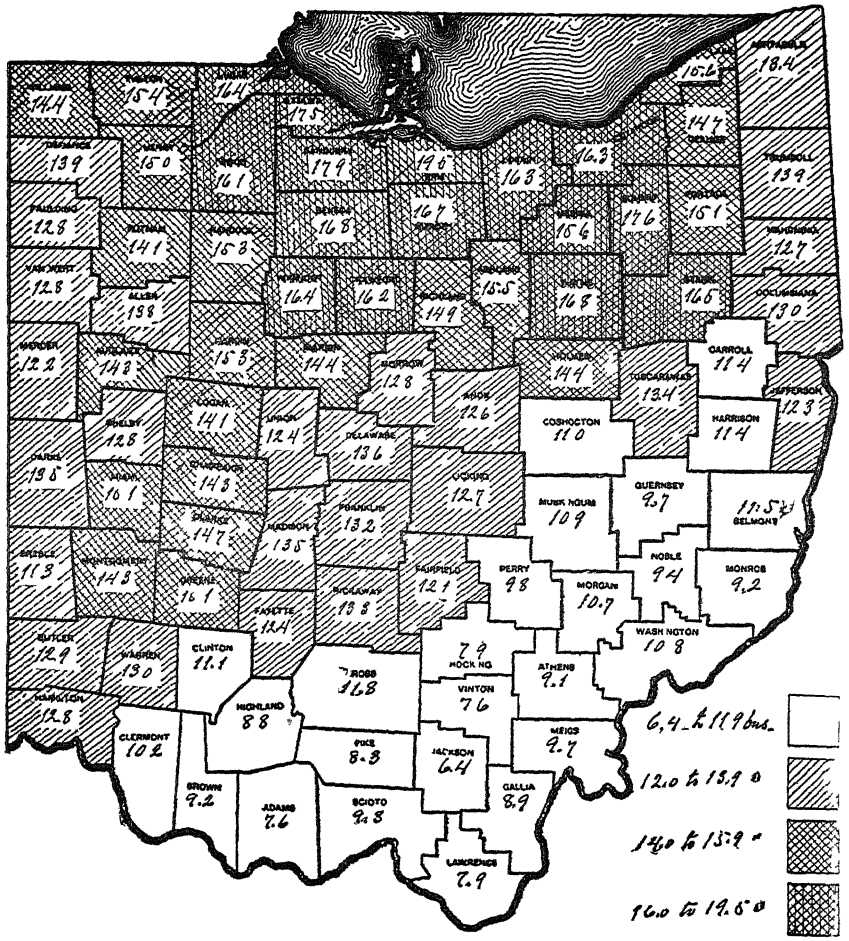
MAP II.—AVERAGE YIELD OF WHEAT IN OHIO FOR THE TEN YEARS 1860-69.



Erratum: In Ross read 9.7 instead of 7.7.

During the sixties, as shown by Map II, the rate of yield fell off generally throughout the State. Erie leads the list throughout this decade with 14.7 bushels, while Montgomery and Ashtabula follow close with 14.5 bushels, and Lake and Miami with 14.2 bushels.

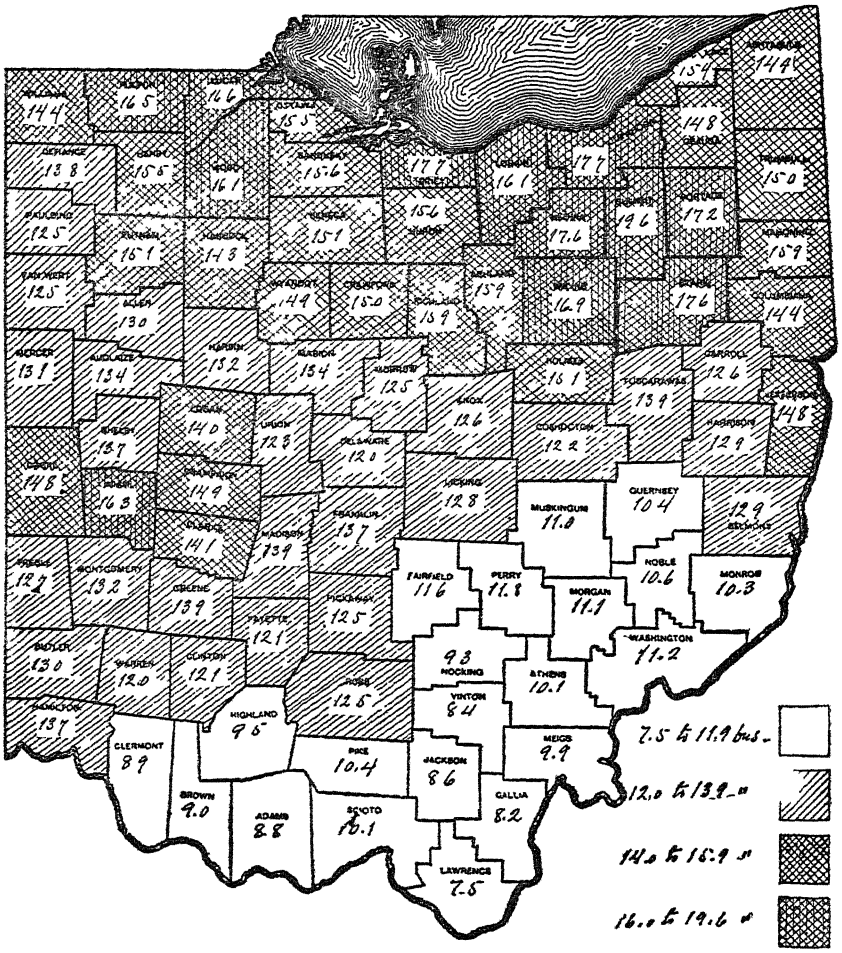
MAP III.—AVERAGE YIELD OF WHEAT IN OHIO FOR THE TEN YEARS, 1870-79.



Errata: In Fulton read 15.9 instead of 15.4, and in Clinton 11 6 instead of 11.1.

During the seventies (Map III) there was a marked increase in rate of yield throughout all portions of the State except the hill counties of the southeast, which remained nearly at a standstill. In the Miami region the increase was small, Greene and Miami being the only counties that reached fifteen bushels, but in the northern region there were twenty-two counties that reached this yield or greater.

MAP IV.—AVERAGE YIELD OF WHEAT IN OHIO FOR THE TEN YEARS, 1880–89.



During the eighties (Map IV) Miami was the only county in that quarter of the State that recorded a yield of fifteen bushels or over, though Champaign and Darke fell but little below, while twenty-four counties in the northern belt recorded a yield equal to or greater than this.

If, now, we take either of these four maps and draw a line due west across the State, from the point where the Ohio river enters it, we shall find that this line approximately separates two distinctly marked areas, in which the average yield of the portion of the State north of the line is very decidedly greater than that to the southward.

It is probable that the superior productiveness of the wheat fields of the northern counties is largely due to the greater snowfall of that region,

but unfortunately no statistics have as yet been collected which throw any decisive light upon this point. (I am assured, however, that it is the intention of the State Meteorological Bureau to collect such statistics in future.) Before discussing this question further we will briefly consider the use of commercial fertilizers in Ohio.

COMMERCIAL FERTILIZERS IN WHEAT CULTURE

The farmers of Ohio are now spending nearly a million dollars annually in the purchase of commercial fertilizers, which are chiefly used in the production of wheat. These fertilizers were not purchased in large quantity previous to 1875, but since that date their use has rapidly increased. Since 1880 the township assessors of the State have been required to collect statistics showing the expenditure each year for fertilizers applied to the wheat crop. These statistics have now been collected for ten years, and it would seem that they, in connection with the statistics of wheat acreage and production, which have been similarly collected since 1850, ought to furnish data by which we might form some judgment as to the effect the use of such fertilizers is having upon the yield of wheat in Ohio. These statistics are compiled in the office of the Secretary of State, and published in the annual volumes of "Ohio Statistics."

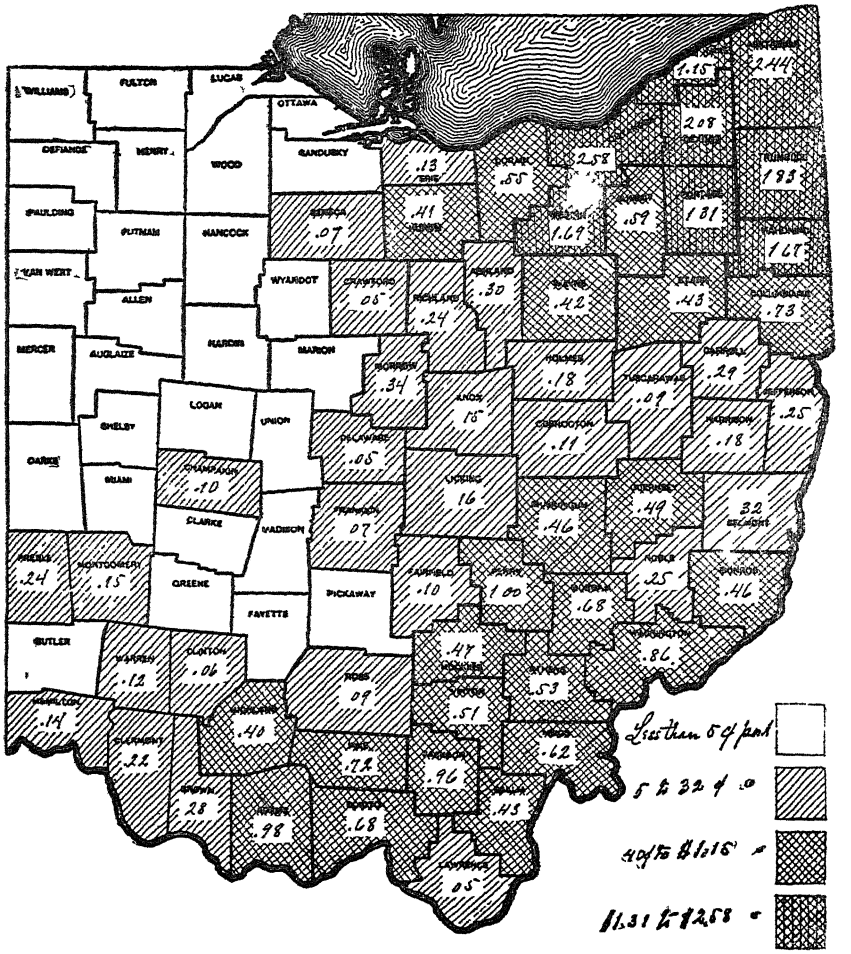
According to the published statistics the wheat crop of Ohio in 1881 received fertilizers valued at $416,476, while the value of the similar application to the crop of 1889 is stated to be $1,675,270. But a glance at these tables shows that there has been gross carelessness in their collection or compilation, one or both, especially during recent years, as when Cuyahoga county is made to use $379,619 worth of fertilizers in 1889 on 9,798 acres of wheat—nearly $40 per acre! On the next page of the same report Cuyahoga is reported as using 2,224,210 pounds of fertilizer, or 1,112 tons, which, at a fraction over $34 per ton, would amount to $37,961—a sum obtained by moving the decimal point one digit to the left. We must still conclude, however, that this total sum includes the cost of fertilizers applied to other crops than wheat, as it is not likely that the entire area sown to wheat in that county received fertilizers at a rate costing $4 per acre.

This is but one of many similar cases which render it impossible to use with assurance these statistics which have been collected at great cost, and whose value would be beyond computation were they accurate. Yet it is possible, with a little experience in the use of statistics and a practical familiarity with Ohio's agriculture, to glean from them some valuable suggestions.

By making use of the method of correction just indicated, and by

comparing the reported expenditure for one year with that for the years preceding and following, Map V has been compiled, in which the average annual expenditure for fertilizers for each acre sown in wheat in the various counties is shown for the ten years ending with 1889 (Map V).

MAP V.—COMPARATIVE USE OF COMMERCIAL FERTILIZERS IN OHIO, 1880–89.



From this map it appears that there are two large districts in the State within which the average annual expenditure for fertilizers exceeds forty cents for each acre of wheat sown; these districts comprise fourteen counties in the northeastern corner of the State and sixteen of the southeastern and southern counties. It will be noticed that the average expenditure is very much greater in the northeastern than in the

southern counties. The two districts named are separated by a group of fourteen counties in which the expenditure ranges from nine to thirty-four cents per acre. Seven of the southwestern counties show an expenditure of six to twenty-eight cents per acre, and nine counties lying on the margin of the districts named show an expenditure of five to thirteen cents per acre, while in twenty-nine counties, lying chiefly in the northwestern and central portions of the State, the expenditure has been less than five cents per acre.

MAP VI.—SECTIONAL DIVISIONS OF OHIO.

A careful study and comparison of all the foregoing maps will show that wheat culture in Ohio has been subject to influences, natural or artificial, which have acted very unequally in different sections of the

State, and yet have operated quite uniformly over areas of considerable extent in each section. It will now facilitate our inquiry if we divide the State into sections, grouping the counties in such manner as to study more in detail the effect of these various influences.

In Map VI the State has been divided for this purpose into seven sections, each containing from seven to twenty counties. This division is largely arbitrary; it depends partly upon latitude, partly upon geological formation, partly upon drainage, natural or artificial, and partly upon the methods of agriculture prevailing in the various sections.

Beginning with the northeastern counties, Sections I and II comprise the counties of the Western Reserve, with the addition of a tier of counties on the south and west. These counties are separated into two sections—eastern and western—because of the smaller use of fertilizers in the western section.

Section III comprises fourteen counties, lying in the region drained chiefly by the Maumee and its tributaries. This region is a great, flat plain, a large portion of which was formerly known as "The Black Swamp," because of the slowness with which drainage waters escaped through natural channels, but which has been so far reclaimed by artificial drainage that it is rapidly taking rank as the most productive portion of the State.

Section IV comprises thirteen counties, drained chiefly by the Miamis.

Section V comprises twelve counties, nine of which are drained by the Scioto and its tributaries, and three by the head waters of the Muskingum and Hocking. The eastern and southern boundary of this section is also approximately the boundary of the drift region in this part of the State.

Section VI comprises seven counties in the eastern portion of the State, and is separated as a transitionary area between the counties to the north and those to the south of it.

Section VII comprises the hill counties of the State—an area bordering the Ohio river, and embracing two or three tiers of counties across the southeastern and southern side of the State. This section contains twenty counties, fourteen of which lie over the coal measures and six over the older rocks to the west of the Scioto. But little of the area covered by these counties has been modified by the drift, but there have been immense changes wrought by erosion, and a very large portion of the original soil has been washed away to form the great flood plain of the lower Mississippi.

Table II shows the relative area in wheat and the average yield per acre for each county and section during each of the ten-year periods

under review, and the average cost of fertilizers per acre of wheat sown during the last decade. In this table the "area in wheat" means the percentage of the "total number of acres owned," as reported in the statistical report for 1889, which the average area in wheat during each decade constitutes; this "total number of acres owned" being assumed to represent, with approximate accuracy, the total area of the farms of the State. It will be seen from this table that there has been a large increase in the area annually sown to wheat in all parts of the State, except the eastern and southeastern sections—the hill counties.

The means of Table II are collected in Table III for greater convenience of comparison. A glance at this table shows that there was a marked advance in average rate of yield of wheat during the seventies, an advance which, at first sight, seems to have been maintained through the decade following. Reference to Table I will show that this advance took place, not at the beginning, but toward the latter part of the eighth decade, and that it was therefore coincident with the general use of commercial fertilizers. Noting this coincidence, the increased yield has naturally been ascribed to the use of these fertilizers.

TABLE II.—Wheat in Ohio by Decades.

Section I.—North-eastern Counties.

Counties.	Area in wheat.				Yield per acre.				Gain or loss in last decade.	Cost of fertilizers per acre.
	1850–9.	1860–9.	1870–9.	1880–9.	1850–9.	1860–9.	1870–9.	1880–9.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	
Ashtabula	1.5	2.0	2.8	5.2	12.9	14.5	13.4	14.4	1.0	$2 44
Lake	4.1	3.8	3.9	5.6	13.5	14 2	15.6	15.6	.. ..	1 15
Lorain	2.4	3.3	4.8	8.4	13.4	13.2	16.3	16.1	—0.2	55
Cuyahoga	2.1	2.2	2.5	5.4	12.4	12.6	16.3	17.7	1.4	2 58
Geauga	1.1	1.3	1.7	3 9	12.8	12.5	14.7	14.8	0.1	2 08
Trumbull	2.8	1.6	2.2	4.1	12.3	12.4	13 9	15.0	1.1	1 83
Medina	5.7	4.7	5.6	10.5	13.8	11.9	15.6	17.6	2.0	1 69
Summit ...	9.7	8.1	9.9	13.5	15.3	13.1	17.6	19.6	2 0	59
Portage	4.0	2.9	3.8	7 0	12 8	12.3	15.1	17.2	2.1	1 31
Mahoning	6.3	4.3	4.9	6.6	12.1	11.6	12.7	15.9	3.2	1 67
Wayne	12.9	11.3	13.8	18.6	12.6	13 2	16.8	16.9	0.1	42
Stark	16.3	13.7	16.3	19.7	15.0	13.4	16 5	17.6	1.1	43
Columbiana	9.7	6.3	7.0	8.9	11.1	10.7	13.0	14.4	1.4	73
Means	6.0	5.0	6.1	9.0	13.1	12.7	15.2	16.4	1.2	$1 34

Section II.—North-central Counties.

Ottawa	2.3	4.6	8.4	14.3	14.6	12.0	17.5	15 5	—2.0	.....
Sandusky	6.3	9.9	15 3	21.1	14.0	12.6	17.9	15.6	—2.3	.....
Erie	7.0	10.1	13.3	17.9	16.7	14.7	19.5	17.7	—1.8	$0 13
Seneca	10.2	11.5	15 9	20.4	13.4	13.8	16.8	15.1	—1.7	07
Huron	5.4	7.2	8.8	12.7	14.1	13.8	16 7	15.6	—1.1	41
Wyandot	3.6	6.8	10.2	14.3	12 6	13.0	16.4	14.9	—1.5	....
Crawford	7.2	8.4	11.6	15.4	11.7	13.0	16.2	15.0	—1.2	05
Richland	9.1	8.8	9 3	12.9	12 3	12.8	14.9	15.9	1.0	24
Ashland	10.9	9.8	12.1	16.7	12.7	12.2	15.5	15.9	0.4	30
Means	6,9	8,6	11,7	16,2	13.6	13.1	16.8	15.7	—1,1	$0 13

Section III.—North-western Counties.

Williams	3.8	8.0	10.9	13.2	10.9	12.3	14.4	14.4	.....	.....
Fulton	3.6	6 5	9.5	13.3	12 9	13.4	15.9	16 5	0.6	.....
Lucas	3.2	7 3	8 5	13.7	13 8	13 8	16 4	16 6	0 2	.....
Defiance	3.0	7 3	8 8	12.8	11.2	11.9	13.9	13.8	—0.1	.....
Henry	1.5	5 2	9 4	17 1	14.2	12.3	15.0	15.5	0.5	.....
Wood	2.0	4 3	6.9	12.4	12 3	12.8	16.1	16.1	.....	.....
Paulding	0.9	2.6	4 4	8.9	11.1	10.9	12 8	12 5	—0 3	.....
Putnam	3.2	5.6	8.7	15.5	10.9	10.9	14.1	15.1	1.0	.....
Hancock	6.2	8 8	11.9	17.1	11.8	11.4	15.3	14.3	—1.0	.....
Van Wert	2.6	4.9	6 5	11.5	11.1	9.8	12 8	12.5	—0.3	.....
Allen	6.7	9.1	11.3	15 2	11.6	10.3	13.8	13 0	—0.8	.....
Mercer	5.1	8 5	9.7	13.6	11.2	10.3	12.2	13.1	0 9	.....
Auglaize	4.9	7.2	10.8	17.5	10.2	10.9	14.3	13.4	—0.9	.....
Hardin	2.8	6.4	9.3	16.3	10.4	11.1	15.3	13.2	—2.1	.....
Means	3.5	6.7	9.0	14.1	11.7	11.6	14.4	14.2	—0.2	.....

Section IV.—South western Counties.

Darke	7.7	11.5	13 5	18.7	11.7	12.6	13.5	14.8	1.3	.....
Shelby	5.9	8.0	10.1	16 0	10.7	12 7	12.8	13.7	0.9	.....
Logan	9.6	10.6	12.8	17 2	13.0	13 1	14.1	14.0	—0.1	.....
Miami	15.0	18.9	19.1	25.7	15 3	14.2	15.1	16.3	1.2	.....
Champaign	11.8	12.7	12.5	17.7	13.2	13.9	14.3	14.9	0.6	$0 10
Clark	16.0	17.5	18.3	23.4	14.7	13.5	14 7	14.1	—0.6	.....
Preble	11.0	14.1	12.1	14.9	13.7	12.2	11 3	12.7	1.4	24
Montgomery	12.8	16.1	15 4	19 9	17.1	14.5	14 3	13.2	—1.1	15
Greene	12.9	15.1	16.7	23.3	15 5	12.4	15.1	13.9	—1.2	.....
Butler	15 9	19.2	16.3	22.4	15.0	12 1	12 9	13.0	0.1	.....
Warren	12.4	13.4	10.8	15.4	14.7	11.6	13 0	12.0	—1.0	12
Clinton	9.5	11 6	10 3	16.1	12.8	10.3	11.6	12.1	0 5	06
Hamilton	11.6	13 2	9.3	13.1	14.7	10.7	12.8	13.7	0.9	14
Means	11.7	14.0	13.6	18.8	14.0	12.6	13.5	13.7	0.2	$0 06

TABLE II—Concluded.

SECTION V.—CENTRAL COUNTIES.

Counties.	Area in wheat.				Yield per acre.				Gain or loss in last decade.	Cost of fertilizers per acre.
	1850-9.	1860-9.	1870-9.	1880-9.	1850-9.	1860-9.	1870-9.	1880-9.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	
Marion	3.3	6.9	8.3	15.3	12.0	12.5	14 4	13.4	—1.0	.....
Morrow	5.3	4 5	5.6	8 3	11.4	11.3	12.8	12.5	—0.3	$0 34
Knox	7.7	6.7	8.4	11.9	11.4	11.0	12.6	12 6	....	15
Union	4.0	6.1	7.5	13.1	11.0	10.3	12.4	12 3	—0 1	.....
Delaware	4.0	5.4	6.1	10.5	10.9	10.9	13 6	12 0	—1.6	05
Madison	3.0	3.1	4.1	12.8	12.3	10.8	13.5	13.9	0.4	.....
Franklin	8.5	10.0	11.7	14 2	13.5	11.8	13 2	13.7	0.5	07
Licking	3.6	5.3	7.5	11.1	10.9	10.2	12 7	12 8	0 1	16
Fayette	5.4	6.0	6 7	16 2	13 0	10 9	12 4	12.1	0.3	.....
Pickaway	3.6	10.2	12.3	20.4	13.2	10.4	13 3	12.5	—0.8	.....
Fairfield	12.5	12 5	13.5	17.2	13.2	10 7	12.1	11.6	—0.5	10
Ross	9.9	10.6	10.3	14.8	12.6	9.7	11.3	12.5	0.7	09
Means	**6.3**	**7.3**	**8.6**	**13.3**	**12.1**	**10.9**	**12.9**	**12.7**	**—0.2**	**$0 08**

SECTION VI.—EASTERN COUNTIES.

Holmes	9.2	8.0	9.1	12.0	11.4	11.3	14.4	15 1	0.7	$0 18
Tuscarawas	12.3	9.3	9.8	11.7	11.6	11.0	13.4	13.9	0.5	09
Carroll	11.6	6.2	6.9	7.6	9 9	9.5	11 4	12 6	1.2	29
Jefferson	13.0	7.6	8.3	9.5	11.2	10.9	12 3	14 8	2.5	25
Coshocton	10.5	7.3	8.6	11.6	10 9	9 7	11.0	12.2	1.2	11
Harrison	10.1	5.0	5.9	7.1	10.7	10 2	11 4	12.9	1.5	18
Belmont	12.1	7.1	7.1	8.8	12.2	10.2	11 5	12.9	1.4	32
Means	**11.3**	**7.3**	**8.0**	**9.8**	**11.1**	**10.5**	**12.2**	**13.5**	**1.3**	**$0 20**

SECTION VII.—SOUTHERN COUNTIES.

Muskingum	12.4	7.5	6.5	8.6	11.3	9.3	10.9	11.0	0.1	$0 46
Guernsey	9.3	5.0	5.0	6.3	9.9	8.1	9.7	10 4	0.7	49
Noble	8.2	6 4	6.2	7.1	10.3	8.3	9.4	10.6	1.2	25
Monroe	8 6	5 6	5.4	7.2	10.5	7.4	9.2	10.3	1.1	46
Perry	14.6	9.2	7.9	7.1	10.8	9.4	9 8	11.8	2.0	1 00
Morgan	12.9	7.7	6.9	7.4	11.6	9 1	10.7	11.1	0.4	68
Washington	7.6	6.5	7.4	9.2	11.0	7.9	10.8	11.2	0.4	86
Hocking	9.1	8.2	6.2	5.8	10.0	7.7	7.9	9.3	1.4	47
Athens	8.2	6 5	6.7	5.7	10.6	8.2	9 1	10.1	1.0	53
Vinton	5.9	4.6	4.1	5.3	8 8	7.0	7.6	8.4	0.8	51
Jackson	7.5	7.7	4 9	5.5	8 5	6.8	6.4	8.6	2 2	96
Meigs	10.5	10.1	10.9	10.8	11.2	8.4	9.7	9.9	0.2	62
Gallia	9.2	10.0	11.0	11.1	10 3	7.8	8.9	8.2	—0.7	43
Lawrence	3.7	7.1	7.2	8.8	10.6	9.0	7.9	7.5	—0.4	05
Highland	12.1	12.9	11.5	12 1	11.2	7.9	8.8	9.5	0.7	40
Pike	4.6	5.9	4.9	6.9	9.0	7.7	8.3	10.4	2.1	72
Clermont	10.3	9 8	7.3	8.5	12 3	8.8	10.2	8.9	—1.3	22
Brown	11.9	10.6	9 8	9.7	10.9	8 8	9.2	9.0	—0.2	28
Adams	8.3	9.0	6.2	7.4	10.4	8.2	7.6	8.8	1.2	98
Scioto	4.5	6.5	4.4	5 6	11.0	8.2	9.3	10.1	1.0	68
Means	9.0	7.8	7.0	7.8	10.5	8.2	9.1	9.7	0.6	$0 47

TABLE III.—SUMMARY OF TABLE II.

Sections.	Area in wheat.				Yield per acre.				Gain or loss in last decade.	Cost of fertilizers per acre.
	1850–9.	1860–9.	1870–9.	1880–9.	1850–9.	1860–9.	1870–9.	1880–9.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Bushels.*	*Bushels*	*Bushels.*	*Bushels.*	*Bushels.*	
I. North-eastern	6.0	5.0	6.1	9 0	13.1	12.7	15 2	16.4	1.2	$1 34
II. North-central	6.9	8.6	11.7	16.2	13.6	13 1	16.8	15.7	—1.1	13
III. North-western	3.5	6.7	9.0	14.1	11.7	11 6	14 4	14.2	—0 2	.....
IV. South-western	11.7	14 0	13.6	18.8	14.0	12 6	13.5	13 7	0.2	06
V. Central	6.8	7.3	8 6	13.8	12.1	10 9	12 9	12 7	—0.2	08
VI. Eastern	11.3	7.3	8.0	9 8	11.1	10 5	12.2	13 5	1 3	20
VII. Southern	9.0	7.8	7.0	7 8	10.5	8.2	9.1	9.7	0.6	47
State	7.9	8.1	9.1	12.8	12.3	11.0	13.4	13.7	.....	.....

If the use of commercial fertilizers has produced a marked increase in the yield of wheat, it should be shown by a comparison of the average yields of the different counties over the last two decades, for the quantity used previous to 1880 was so small that it can not have had any great effect upon the total crop. Such a comparison is made in Tables II and III, the last two columns showing respectively the increase or decrease in average yield per acre for the last decade, as compared with the one immediately preceding, and the average cost of commercial fertilizers for each acre of wheat sown during the last decade.

In the north-eastern counties we find that there has been a general increase in yield per acre, over these two decades, although in Lake, Geauga and Wayne the increase is too small to have any significance, while in Lorain a slight loss is shown. The average increase for this section is about five pecks per acre, and the average cost of fertilizers $1.34 per acre.

Attention is called to the fact that the increase in Summit county has been the same as that of Medina and Portage, between which it lies, although its rate of expenditure for fertilizers has been less than half that of those counties. Either some other cause than the use of fertilizers has been a prime factor in producing the increase of yield throughout this section, or else these fertilizers have been used to much better purpose in some counties than in others.

In the north-central counties we find a surprisingly uniform *decrease* in yield per acre, Ashland and Richland being the only counties in this section which fail to show a falling off in yield, although in both these counties fertilizers are used less extensively than in Huron, which shows a loss of more than a bushel per acre. The average loss for this section is 1.1 bushel, and the average expenditure for fertilizers, thirteen cents. The area devoted to wheat throughout this section is much larger than the average area so used in the north-eastern section, Wayne, Stark and Summit being the only counties in this section whose acreage in wheat equals that of the north-central section. During the twenty years, 1850–69, the average yields of these two sections followed the same course, the falling off during the sixties being practically the same, but during the seventies the yield of the central counties shot far ahead of that of the eastern section. If the yields of the two sections be compared by twenty-year periods the rate of increase will be found to be identical. We must therefore conclude that the fluctuations indicated in the central section are due to climatic changes, causing the rate of yield over large areas to rise and fall in cycles, rather than to the non-use of fertilizers.

In the north-western section we find again a remarkably uniform rate of production throughout the first twenty years, followed by a sudden rise

during the seventies, which is again maintained for twenty years with a very slight downward tendency.

In the south-western and central sections the rate of yield has also been practically at a standstill for twenty years, the fluctuations in these and the north-western counties being too small to justify any inferences.

In the eastern section a marked increase is shown, the amount of increase being practically identical with that in the north-eastern counties, although the expenditure for fertilizers has been relatively only one-seventh as great in the eastern counties as in those to the northward, showing again that if the increase throughout these two sections be due to the use of purchased fertilizers these fertilizers are being used far more effectively in some sections than in others.

In the south-eastern and southern counties an increase is indicated of nearly two-thirds of a bushel per acre, against an expenditure of nearly half a dollar per acre for fertilizers.

The comparison made in Tables II and III may be objected to on the ground that some use of fertilizers was made during the seventies, and therefore that the yield during this period was somewhat increased, thus diminishing the differences shown in these tables. Objection may be raised against a comparison with the ten years, 1850–59, on the ground that during this period the soil was in a state of almost virgin fertility over a large portion of the State. Let us, therefore, compare the yields for the last decade with those for the sixties, a period during which wheat culture sunk to its lowest ebb in Ohio, both in area sown and in yield per acre, the cause being either the exhaustion of the soil under improvident husbandry or the prevalence of unfavorable climatic conditions. This comparison is made in Table IV:

TABLE IV.—Effect of Fertilizers.

Sections.	Yield per acre.		Increase per acre.	Cost of fertilizers per acre.
	1860–9.	1880–9.		
	Bushels.	*Bushels.*	*Bushels.*	
North-eastern	12.7	16.4	3.7	$1 34
North-central	13.1	15 7	2 6	13
North-western	11 6	14 2	2.6	.....
Eastern	10.5	13 5	3.0	20
Central	10.9	12.7	1.8	08
South-western	12 6	13.7	1.1	06
Southern	8.2	9.7	1.5	47

Comparing sections in the same latitude, we find that the north-eastern section has increased its average yield by 1.1 bushel more than

either the north-central or north-western section, and that its expenditure for fertilizers has exceeded that of the north-central section by $1.21 per acre.

Comparing the central and eastern sections, we find that the latter has increased its yield by 1.2 bushel over the former, and that its expenditure for fertilizers has exceeded that of the central section by an average of 12 cents per acre.

Comparing the south-western and south-eastern sections, we find that the increase in average yield in the south-eastern section exceeds that in the south-western section by four-tenths of a bushel per acre, and that the average cost of fertilizers per acre in the former exceeds that in the latter by 41 cents per acre.

Taking the two sections, therefore, in which fertilizers have been used most extensively and for the longest period, and comparing with either of the two decades preceding, it would seem that a dollar expended in fertilizers has produced approximately a bushel of wheat.

This estimate is based on the assumption that these two sections have profited equally with the remainder of the State by the general improvement in methods of agriculture and by the more favorable climatic conditions to which the increase in all other sections of the State must be ascribed It is true, however, that underdrainage, which has undoubtedly contributed much to the increase of yield in the remainder of the State, has done practically nothing for the hill counties; but by no legitimate calculation can the entire increase in yield, as shown by Table IV, be ascribed to the use of fertilizers.

Table IV makes the most favorable exposition of the effect produced by the use of fertilizers that can be drawn from these statistics; but it does not show the real trend of wheat production in the State, because a decade of rather more than average production is compared with one whose yield is far below the average. A more nearly correct idea of this trend may be obtained by comparing the yields of the different sections in two twenty-year periods, although even in this case allowance must be made for the fact that the first period contains a series of abnormally low yields and the second a like series of abnormally high yields. This comparison is made in Table V, the south-western section being subdivided in order to show more clearly the effect of latitude:

TABLE V.—AVERAGE YIELD OF WHEAT IN OHIO BY TWENTY-YEAR PERIODS.

Sections.	Yield per acre.		Increase.
	1850–69.	1870–89	
	Bushels.	*Bushels.*	*Bushels.*
North-eastern	12 9	15 8	2.9
North-central	13 3	16 2	2.9
North-western	11 6	14 3	2 7
Eastern	10.8	12 8	2 0
Central	11.5	12.7	1 2
Western	13.2	14 3	1.1
South-western	13 4	13.0	—0.4
Southern	9 3	9.4	0.1

This table summarizes results which are shown in detail, and at the same time more graphically than in the table, in Map VII, in which is given the increase or decrease in average yield of each county for the twenty years ending with 1889, as compared with the twenty years immediately preceding.

This table and map clearly bring out the point already alluded to, that latitude is an important factor in wheat production, although its influence is, of course, modified by local circumstances.

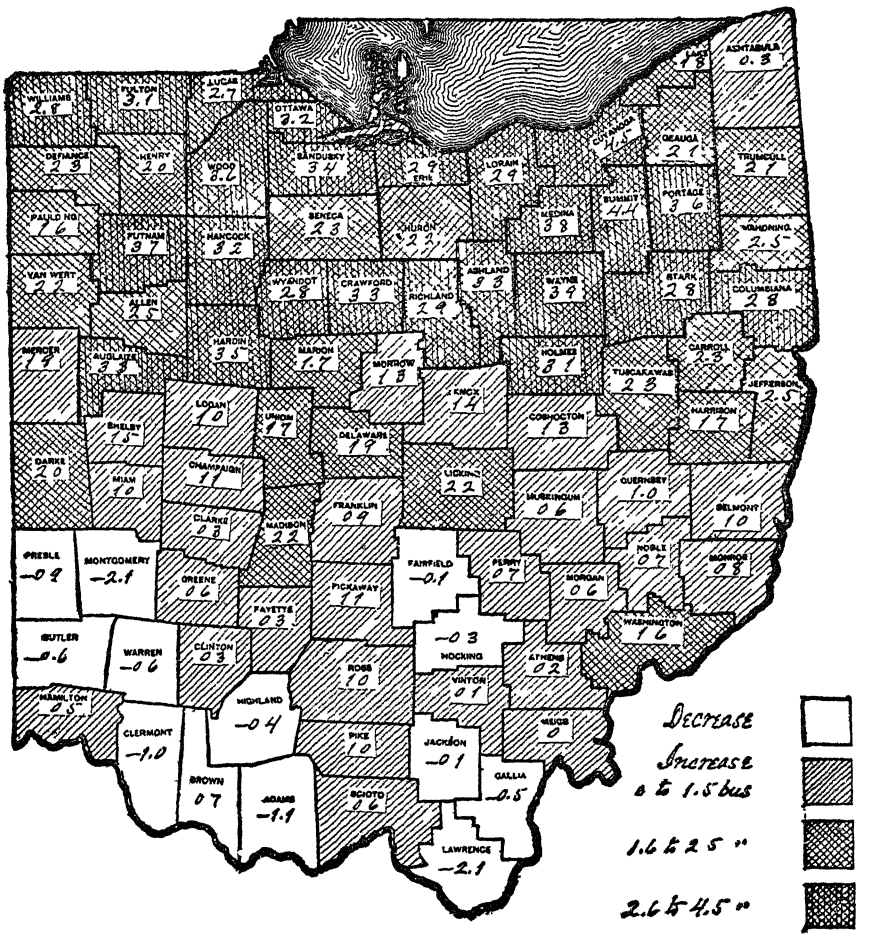
In the Miami valley, for instance, the northern counties show a gain in yield corresponding to the gain of the central and eastern sections, while the southern counties show a retrograde movement, although these counties can not be classed as hilly. The map shows also that the northern counties in the hill region have made some progress, while the southern counties are at a standstill or falling behind. By reference to Map IV it will be seen that the rate of yield in the southern counties of the Miami valley is still considerably above that of the eastern counties lying in the same latitude.

The question now arises: How much of the apparent increase of production during the last twenty years must be ascribed to climatic causes, and how much may be accredited to better husbandry?

An exact answer to this question it is impossible to give. It is, however, a well established fact that underdrainage diminishes the liability of wheat to injury from winter killing, and a large amount of underdraining has been done in Ohio during the last twenty years. It is also reasonable to believe that there has been some improvement in tillage during this period, and that the methods of husbandry in general, including the rotation of crops and the use of manures and fertilizers, are such as to increase, rather than diminish the yield of wheat. It is therefore

fair to assume that a part, at least, of the advance indicated by Map VII and Table V is actual and will be maintained through future years.

MAP VII.—AVERAGE INCREASE OR DECREASE IN YIELD OF WHEAT PER ACRE IN OHIO, 1850–89.



By referring to Table III it will be seen that the depression in average yield during the sixties occurred almost altogether in the middle and southern counties, so that it seems safe to assume that the advance indicated in the northern counties, at least, is an actual gain.

WHEAT CULTURE AND GEOLOGY.

As has already been stated, one of the objects of this statistical study was to endeavor to learn what relation, if any, exists between the geological history of the soil and its yield of wheat.

A glance at the geological map of Ohio shows three broad bands running across the State from north to south. That on the east embraces the coal measures, and extends across nearly one-third of the State; then follows a narrower strip, underlaid with Waverly rocks and bordered by a narrow belt of Huron shales, while the western half of the State lies over limestones.

As the Waverly rocks are chiefly sandstones or calcareous shales, this formation would offer a sharp contrast between soils of such origin and those derived from limestones, were it not for the fact that, in the case of Ohio, both these formations are covered with a thick bed of glacial drift. The drift, however, is considerably modified by the underlying rocks, and it would seem that if there were any marked differences in the value for wheat culture of soils of the widely different character produced from these different formations it should be indicated in this case.

Omitting the four counties in the north-western corner of the State, which overlie the outcrop of Huron shale in that region, viz : Williams, Fulton, Defiance and Henry; the five counties which lie on both sides of the belt of Huron shale, extending north and south through the State, namely: Erie, Crawford, Delaware, Franklin and Pickaway, and the five counties lying immediately north of the coal region and chiefly over conglomerates, namely: Lake, Geauga, Ashtabula, Summit and Trumbull, the remaining seventy-four counties have been divided into three parallel belts, according to latitude, and subdivided according as they lie over the limestones, shales or coal measures, making nine groups in all.

In the northern belt are included twelve limestone counties, viz. Lucas, Ottawa, Wood, Sandusky, Paulding, Putnam, Hancock, Seneca, Van Wert, Allen, Hardin and Wyandot; seven counties over the Waverly, viz.: Lorain, Cuyahoga, Huron, Medina, Richland, Ashland and Wayne, and six counties over coal, viz.: Portage, Mahoning, Stark, Columbiana, Holmes and Carroll.

In the middle belt are eleven limestone counties, viz.: Mercer, Auglaize, Marion, Shelby, Logan, Union, Darke, Miami, Champaign, Clark and Madison; four Waverly counties, viz.: Morrow, Knox, Licking and Fairfield, and seven coal counties, viz.: Coshocton, Tuscarawas, Harrison, Jefferson, Muskingum, Guernsey and Belmont.

In the southern belt are twelve limestone counties, viz.: Preble, Montgomery, Greene, Fayette, Butler, Warren, Clinton, Highland, Hamilton, Clermont, Brown and Adams; three Waverly counties, viz.: Ross, Pike and Scioto, and twelve coal counties, viz.: Perry, Morgan, Noble, Monroe, Hocking, Athens, Washington, Vinton, Meigs, Jackson, Gallia and Lawrence.

In the following table is given the average yield per acre of each of these groups of counties for the forty years under review, and for each of the two twenty-year periods, and the average increase in yield per acre during the last twenty years:

TABLE VI.—YIELD OF WHEAT IN OHIO BY GEOLOGICAL DIVISIONS.

Yield and Increase in Bushels per Acre.

Groups.	40 years, 1850–89.	20 years, 1850–69	20 years, 1870–89.	Increase or decrease (—).
Northern Belt—				
12 limestone counties	13.5	12.1	15.0	2.9
7 Waverly "	14 6	12.9	16.3	3 4
6 coal "	13 2	11.8	14.7	2.8
Middle Belt—				
11 limestone counties	13 0	12.2	13.8	1.6
4 Waverly "	11 8	11.2	12.4	1.2
7 coal "	11.2	10.5	12 0	1.5
Southern Belt—				
12 limestone counties	11.8	12.1	11 6	—0 5
3 Waverly "	9 9	9 5	10 4	0.9
12 coal "	9.2	9.2	9.3	0.1

From this table it appears that in the northern belt the counties over Waverly rocks have given a larger average yield over the entire forty-year period under review than those in the same latitude, which are underlaid with limestones or with the rocks of the coal measures, and that the rate of increase in yield during the past twenty years is also larger in the counties over the Waverly.

In the middle belt the result is just the opposite; the limestone counties show the larger yield and the greater rate of increase.

In the southern belt the limestone counties show the larger yield, but the Waverly counties show a greater rate of increase.

The counties overlying the coal measures stand below either of the other divisions in yield per acre in each of the belts, the difference increasing in the more southerly latitudes. In rate of increase they stand between the other two divisions. The topography of these hilly, coal counties, is a sufficient cause for their lower yield, and is probably the chief cause, as the rocks of the coal measures comprise both limestones and shales, and it is probable that the soils derived from them are not naturally inferior in fertility to those found in the remainder of the State.

As between the soils lying over limestones and those over shales, these statistics do not yet justify any opinion regarding their respective adaptation to the production of wheat. It is probable, however, that the

middle and southern belts of counties afford a more just basis of comparison between the two geological formations than the northern belt, because in this northern region the overlying drift has been derived, to a large extent, from the rocks excavated from the lake basin, and which are both limestones and shales.

THE FUTURE OUTLOOK.

Within twenty years the area annually sown to wheat in Ohio has increased from an average of 1,800 000 acres during the eighth, to 2,500,000 acres during the ninth decade. This area represents twelve per cent. of the area in farms within the State, but several counties are sowing annually 18 to 20 and even 25 per cent. of their farm lands to wheat. In 1881 a total area of 2,800,000 acres was sown, and there is no good reason to doubt that with the continued clearing away of the forest and the reclamation of waste lands by drainage it will soon be possible to devote as much as 3,000,000 acres to wheat without infringing upon any other agricultural interest, and this, even though the hill counties should reduce their acreage by one-half. Such an increase, at the present rate of production, would represent an annual product of 40,000,000 bushels.*

But it is not to be supposed that Ohio farmers will rest content with a yield of only thirteen bushels of wheat per acre. As has already been shown, the northern third of the State has increased its average yield within forty years by nearly three bushels, and the middle third by from one to two bushels, and it is reasonable to expect a similar increase within the next forty years, notwithstanding the fact that the rate of production seems just now to be at a standstill. It is to be expected that progress in this, as in other matters, will be more or less spasmodic, and that its actual rate can only be measured at long intervals; but it is not impossible that the time may come when the average from the entire State will equal the present average of Summit county, which means a total average production of about 60,000,000 bushels, or bread for twelve million mouths. Such a yield would be far below what has been attained in Great Britain, where the average yield is now 28 bushels or more per acre and is steadily increasing. This high yield is not due solely to the superiority of the soil and climate of that country, for the time has been when the average yield of Great Britain was very much smaller than it is at present.

Ohio's population has increased by a little more than two millions since 1850, while the total wheat yield has increased by an average of more than 14,000,000 bush. per annum, comparing the average of the first decade with that of the decade 1850–9, so that production is keeping far ahead

*43,000,000 bushels were harvested in Ohio in 1880.

of any possible consumption within the State. Production will eventually reach a limit, while population may expand indefinitely, but at present rates of increase, both of population and of wheat production, it will probably be several centuries before Ohio shall contain enough people to consume all her wheat.

What is true of Ohio is true to a greater or less extent of the entire winter wheat belt of North America. The area now sown to wheat in this region may be expanded largely without infringing upon other productions, and the rate of yield may and will be very materially increased by better husbandry, including an intelligent use of manures and fertilizers, and more thorough drainage.

Let there be given a little stimulus in the shape of higher prices for wheat and we shall see a rapid expansion in the total production in this country, while there are still undeveloped regions in South America, South Africa and Australia, which will eventually be made to add largely to the world's supply of breadstuffs.

This is not said by way of discouragement. I believe that the future outlook for the Ohio wheat grower is eminently a hopeful one, but I do not expect to see the very great increase in price of wheat that is being predicted by certain statistical writers. In my judgment, the great opportunity for the Ohio wheat grower lies in increasing the yield per acre, in reducing the cost of production and in improving the quality of the grain. Such a course will render him independent of the market, and then if higher prices do come he will be doubly benefited.

CONCLUSIONS.

It appears from this statistical study of the wheat harvests of Ohio that the average yield of wheat is increasing in the northern and central sections of the State, while it is at a standstill, and standing at far too low a point for profit, in the southern and south-eastern counties.

It would seem that the profitable culture of wheat on the steep hillsides of southern Ohio is a hopeless undertaking; that the great problem before the wheat grower of the central belt of counties is winter-killing, a problem which may be partially solved by underdrainage and the intelligent use of clover and manures; and that in the northern counties climatic influences are more generally favorable to wheat culture than elsewhere in the State.

These statistics indicate that the wheat crops of Ohio have been slightly increased by the use of commercial fertilizers, but it appears that the average cost of this increase has equaled its market value, and that a general improvement in the methods of agriculture has contributed

more largely to the increase of Ohio's wheat crops than the use of purchased fertility.

It would seem that the total area under wheat might be considerably enlarged, and at the same time more closely restricted to lands adapted to tillage, and that the yield per acre may be so increased that the total product shall reach double the quantity now annually produced

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